Minderoo Foundation – *OceanOmics* Program

Ocean: the continuous body of salt water that covers more than 70 percent of the Earth's surface
Omics: novel, comprehensive approaches for analysis of complete genetic or molecular profiles

The situation

The oceans are in the midst of a crisis of biodiversity loss due to overfishing, climate change and plastic pollution. We know that some iconic marine predators like bluefin tuna and oceanic whitetip sharks are threatened with extinction, but almost nothing about the conservation status of the myriad other species that inhabit the ocean.

With the majority of the ocean's biodiversity effectively unmapped and unknown, it has been too easy for decision makers to disregard the crisis that is occurring underwater and out of sight – even though the climate of our planet and the livelihood of 3 billion people depend directly on it.

Ground-breaking technologies that enable ocean wildlife populations to be monitored robustly at speed and scale are needed to gain consensus among policy makers and protect our ocean before it is irreversibly degraded. You cannot protect what you cannot measure.

One such technology is genomics. But whole-genome and single-cell sequencing remain cost-prohibitive and difficult to deploy at ecological scales. Progress in the field of conservation genomics hinges on such challenges being solved and the development of a "Rosetta Stone" – a reference genome library – for marine life.

Our purpose

As one of Asia's largest philanthropic organisations, Minderoo Foundation is uniquely positioned to develop innovative, high-risk and scalable solutions to the planet's biggest problems. Minderoo's Flourishing Oceans Initiative (FLO) aims to expand marine protected areas, protect marine environments and global fish stocks and expand Western Australia's marine research capabilities.

The *OceanOmics* program will contribute to these objectives by accurately measuring life in the oceans so that it can be protected – with a focus on three initial goals:

- Support 30 by 30 - the conservation of 30% of the world's ocean by 2030 – and ensure >95% of the ocean's genetic biodiversity is protected by quantifying genetic health within current protected areas (MPAs) and identifying new regions in need of protection
- Generate the first ocean vertebrate genome reference library, as both an important enabler to accelerate genomics research and ocean conservation and a lasting, global legacy
- Develop the required novel sequencing and bioinformatics techniques and integrate these on board a breakthrough ocean monitoring platform in the form of a dedicated research vessel that will enable data collection and analyses at an unprecedented speed and scale

Specifically, data will be used to:

- Identify and quantify the epicentres of ocean genetic diversity and ensure their protection
- Assess species biodiversity, population structure, abundance, distribution and gene flow
- Monitor "keystone" species and vulnerable ecosystems to conserve genetic health/diversity
- Improve our understanding of regional/global connectivity between populations and stocks
- Support trans-national agreements and the conservation of new and over-exploited species
- Understand the relationship between plastic pollution and genetic health/distribution

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VIEWPOINT

The *Panthalassa* project: The future of ocean research for conservation

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> 'Our business is to rectify Nature to what she was…'.
>
> John Donne, 1610

Unless you are standing in the Hajar Mountains in eastern Oman or on the Troodos Ophiolites in Cyprus, the ground beneath your feet was once, 250 million years ago, part of a single supercontinent surrounded by a single ocean, Panthalassa. The time it took the scientific community to accept that continents can move was, arguably, equally geological. Indeed, a 400-year old suspicion only accelerated into scientific consensus in response to large-scale, high-quality datasets, and the lessons learned furnish a rich and instructive analogy about how we might create a global consensus in ocean conservation today.

In the 16th century, mapmakers gazed, perplexed, upon the coastlines of distant continents: why on Earth did they fit together, like a jigsaw puzzle? It was only in 1912 that Alfred Wegener made the first convincing case for continental drift, proposing that the world's continents were once part of a single landmass, Pangaea, and had *moved* to their current positions. The evidence was overwhelming. Nevertheless, until the 1950s, many geologists preferred to believe that some continents had simply sunk to create the modern map of the world, with long-gone land bridges acting as intercontinental highways. In the 1960s, large-scale, high-quality maps of the ocean floor and earthquake hypocentres finally became available, and the sheer explanatory fire power of plate tectonics in support of Wegener's case finally sank the land-bridge theorists.

The key point is that ocean-scale, uniformly high-quality datasets exploiting relevant new technologies, integrated by multidisciplinary thinkers and well communicated to policy makers, are needed to drive action around urgent planetary problems like the crisis in marine extinctions, our subject here.

The oceans are on the cusp of a crisis of biodiversity loss due to overfishing, climate change and plastic pollution. Indeed, this year marked the first year that a species of marine fish has gone extinct in modern times. Many top marine predators, including the hammerhead shark, oceanic whitetip, shortfin mako and bluefin tuna – the Rolexes of Richard Dawkins' 'blind watchmaker' – are on the verge of extinction. The number of fish stocks that are overfished continues to rise and the twilight zone, home to 20 billion tonnes of wildlife – 40 times the weight of humankind – is poised to become the global fishing industry's next target (John et al., 2016; Martin et al., 2020).

Yet platforms that obtain compelling data in support of marine conservation remain expensive and underfunded. Ocean science accounts for just 0.04–4% of national R&D budgets and just three countries, Japan, the Russian Federation, and the United States, own over 60% of the existing 325 research vessels (IOC-UNESCO 2017). Of these vessels, 43% are limited to coastal research and only one-fifth are large enough (>65 m) to conduct research at a global scale. Moreover, the global research fleet is increasingly decrepit, with 96% of large (>55 m) research vessels over a decade old, and an average age in Australia, Canada and Mexico of over 45 years. Philanthropists are increasingly, and, presumably, gingerly, inviting marine biologists

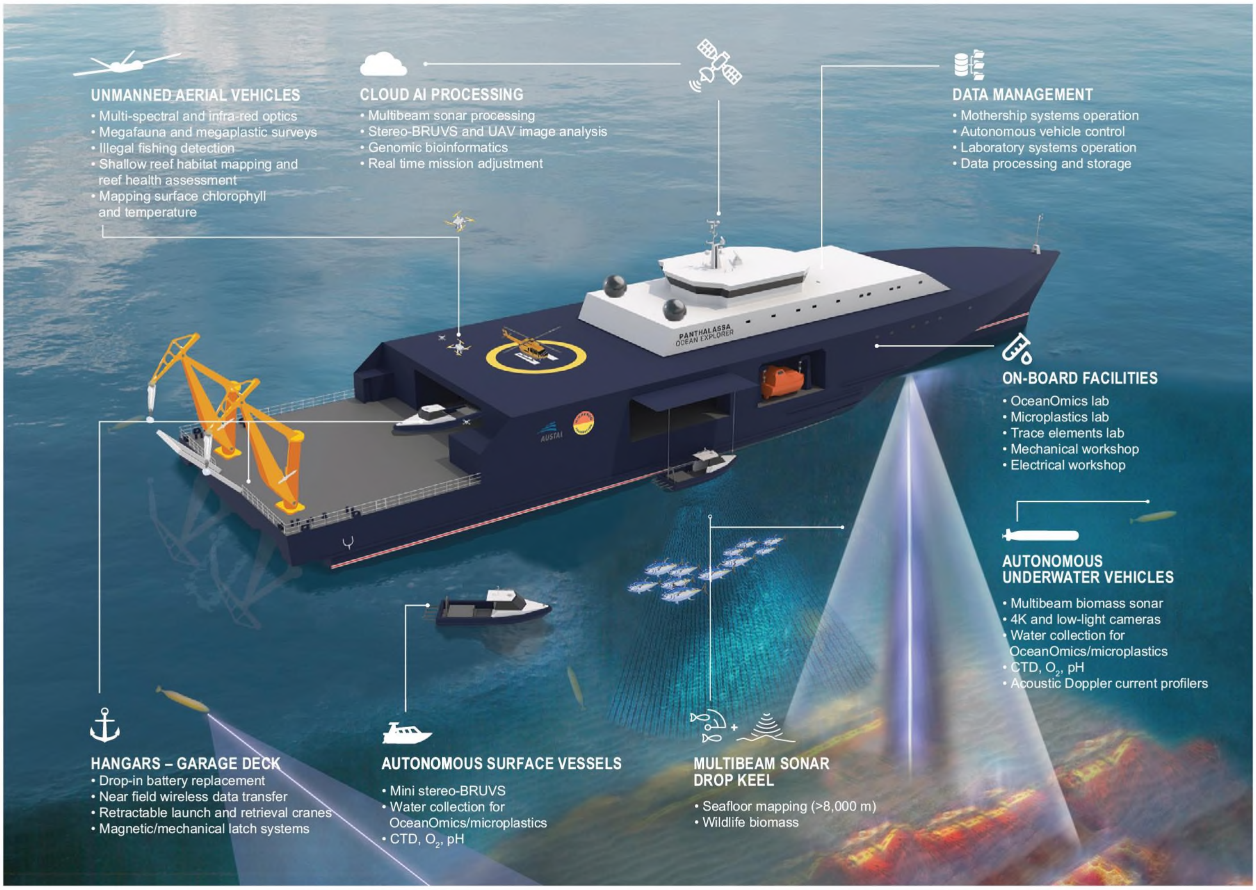

FIGURE 1 Proposed design of the next-generation research platform and trimaran, *Panthalassa Ocean Explorer*

onto their superyachts, but the cumulative capacity of this fleet remains small compared to publicly funded vessels or, indeed, the rusty old trawlers that impoverished PhD students are often forced to hire in order to research remote areas. (Think Steve Zissou's Belafonte, where the most advanced technologies are in the galley.) Moreover, most ocean-going research vessels have low cruising speeds, precluding rapid data collection at large scales.

Here, I present my vision of Panthalassa, the first of a series of next-generation research vessels that I hope will rapidly generate the irrefutable, ocean-scale evidence that is a prerequisite for scientific consensus and policy change.

Panthalassa's trimaran hull will allow her to safely reach speeds in the open ocean of up to 40 knots – almost four times that of the average research vessel. Multibeam sonar will allow her to map the seafloor at depths of up to 8,000 m and estimate wildlife biomass using a ground-truthed library of species-specific acoustic 'signatures'. Long-range autonomous aerial vehicles (AAVs) will conduct wildlife, plastics and illegal fishing surveys, and map surface environmental variables such as chlorophyll. Autonomous underwater vehicles (AUVs) will sample the same variables but at hitherto unprecedented vertical resolutions, allowing exploration of complex, depth-dependent processes in, for example, submarine canyons. These tireless robots will stream live footage to both scientists and to the public, for, as Baba Dioum wrote in 1968, 'in the end, we will conserve only what we love; we will love only what we understand; and we will understand only what we are taught'. Automated surface vehicles (ASVs) will deploy and retrieve miniature versions of stereo underwater camera systems, which will estimate the diversity, abundance, size, and biomass of pelagic life (Bouchet & Meeuwig 2015; Forrest et al. 2020). The ASVs and AUVs will also collect and deliver filtered water samples to the home ship to be analysed for microplastics and other pollutants (Figure 1).

Panthalassa's most defining technologies, however, will lie in the field of genomics and bioinformatics. The power of sampling fragments of genetic material (eDNA) from the ocean is well understood, but single cell sequencing, applied to intact whole cells, will transform marine conservation. When I learned of this technique through Minderoo Foundation's Collaborate Against Cancer initiative in 2018, its potential applications were immediately clear: how transformative it would be if we could rapidly document ocean wildlife – not only species diversity, but also age, sex and population size – using nothing more than a cup of sea water? Such an advance would not only revolutionise our ability to protect endangered species but also provide an early warning system to detect declining wildlife.

'Ah, but a man's reach should exceed his grasp, or what's a heaven for?' wrote Robert Browning in 1855. Many of you are probably thinking: this sounds like heaven, but is it actually achievable? In March, we established Minderoo's OceanOmics initiative to develop this program. In the second half of 2020, COVID-19 permitting, we will pilot single cell sequencing methods on *Panthalassa*'s little sister, the 58-m *Pangaea Ocean Explorer*, at the Great Barrier Reef. Some techniques will fail and be discarded; others will fail and give rise to new ones; some will succeed dramatically. A prerequisite to achieving our ambitions will be the development of a whole-genome library for marine life: fewer than 0.5% of Australia's saltwater fish species (20 of 4,379) have been fully sequenced to date, according to the National Centre for Biotechnology Information database.

Will *Panthalassa*'s ocean-scale, high-quality datasets catalyse rapid change in marine policy, given the slow response of policy makers to other scientific evidence (e.g., climate change)? I would argue that policy processes must evolve rapidly in step with our research platforms, becoming almost automated in their responsiveness to robust scientific evidence. Indeed, governments wishing to use platforms like *Panthalassa* to monitor their Exclusive Economic Zones will need to agree *a priori* to apply IUCN II or stronger protection to any habitat identified as ecologically valuable before data are released – thus ensuring that sensitive information (e.g., locations of biodiversity hotspots or populations of endangered species) is not misused.

Philanthropists are uniquely positioned to innovate, to take and absorb risk – in contrast to governments, which are risk-averse, wary of the political consequences of failure and accountable to taxpayers. Once *Panthalassa* has tested the hypothesis that high-speed, large-scale data collection can accelerate ocean conservation, I challenge my peers, globally, to replicate her approach and support their governments, providing them with the platforms they need to protect the immensely valuable assets that lie within their Exclusive Economic Zones (EEZs). With global fishing fleets increasing in range, fuelled by absurd subsidies, modern slave labour and dwindling local fish stocks, distance and depth no longer represent an obstacle to exploitation. We must act now, if we are to return our ocean to a flourishing state. A heaven is within reach – if we are determined and prepared to fail along the journey.

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The program

OceanOmics' ambitious aim is to drive the development of breakthrough techniques that enable rapid, population-scale monitoring of the health of ocean wildlife populations.

The team and our collaborators, comprised of exceptional geneticists, bioinformaticians and marine engineers, will be dedicated to innovation, scientific exploration, data-sharing and a rigorous industry-style approach to technology acceleration and real-world application.

Our *OceanOmics'* laboratories will include a specialised sequencing and informatics facility in Perth, Western Australia as well as a unique shipboard lab that will be trialled on board our 58-metre research vessel, *Pangaea Ocean Explorer* in 2020/21, prior to the planned construction of a custom, 120-metre, high-speed research trimaran, *Panthalassa Ocean Explorer* (Forrest, 2020*).

In collaboration with leading international centres of excellence including the Wellcome Sanger Institute's Tree of Life project, Rockefeller University and the Vertebrate Genome Project we will establish the first reference genome centre and library for marine vertebrate species.

The program will work with Governments around the world to inform policy and ensure protection of fully representative marine biodiversity and ecosystems, including default protection for vulnerable or threatened species as well as newly identified stocks, populations and species. The onus for determining the sustainable yield of any exploited stock must rest with industry.

Additional Minderoo Foundation assets and initiatives directly relevant to *OceanOmics* include:

- The $130 million *Forrest Research Foundation* attracts outstanding scholars to Perth in partnership with the leading universities within Western Australia;
- A state-of-the-art, *marine research centre* at Exmouth, Western Australia in the heart of the UNESCO-listed Ningaloo World Heritage site in the eastern Indian Ocean, presents opportunities for collaboration with researchers from around the world;
- The launch of a *Global Fishing Index* to be published in early 2021 providing accepted data on the sustainability of the world's fisheries;
- Our $300 million *Sea The Future* program to end plastic waste through establishing a circular economy for plastics and;
- A $180 million, global collaboration to increase to at least 10% the proportion of the world's ocean under IUCN highly protected status.

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